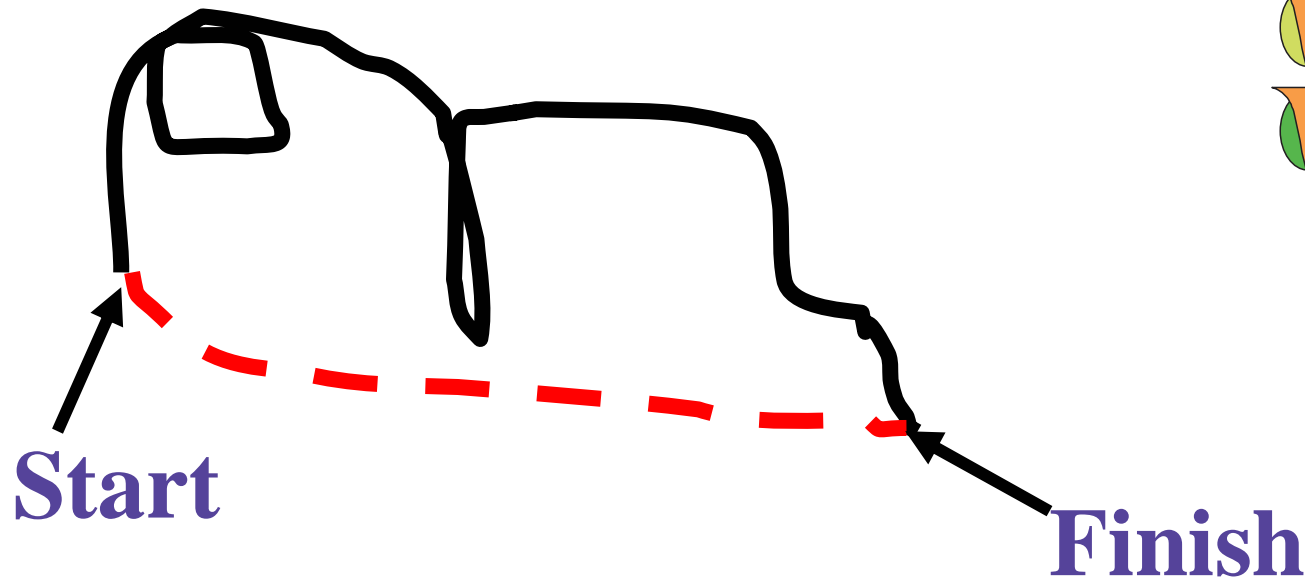
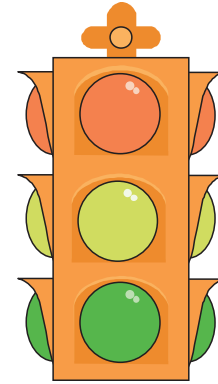


Hess's Law



A State Function: **Path independent.**

Both lines accomplished the same result,
they went from start to finish.

Net result = same.

Germain Henri Hess (1802 -1850)

Hess' Law states that *the heat evolved or absorbed in a chemical process is the same whether the process takes place in one or in several steps.*

In other words:

Since H (enthalpy) is a state function, the ΔH is independent of pathway

Hess' Law- when going from reactants to products in a chemical reaction, the ΔH is the same whether it happens in one step or in multiple steps

Two Techniques for Hess's Law

1. Manipulating chemical reactions algebraically
2. Using an equation by obtaining the enthalpy of formation from a data table

Rules for Manipulate ΔH

1. If a reaction is reversed, the sign of ΔH must be reversed as well.
2. The magnitude of ΔH is directly proportional to quantities of reactants and products in reaction.

If coefficients are multiplied by an integer, the ΔH must be multiplied in the same way.

Determine the heat of reaction for the reaction:



Using the following sets of reactions:



Hint: The three reactions must be algebraically manipulated to sum up to the desired reaction.

and.. the ΔH values must be treated accordingly.



Using the following sets of reactions:



O₂: Found in more than one place, SKIP IT (its hard).





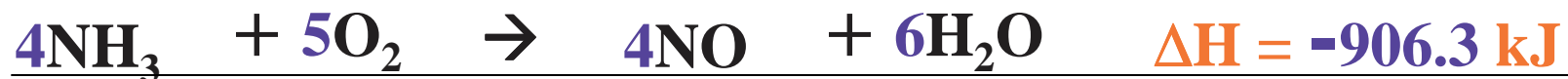
NH₃: Reverse and x2 $4\text{NH}_3 \rightarrow \cancel{2\text{N}_2} + \cancel{6\text{H}_2}$ $\Delta\text{H} = +183.6 \text{ kJ}$

O₂: Found in more than one place, SKIP IT.

NO: x2 $\cancel{2\text{N}_2} + 2\text{O}_2 \rightarrow 4\text{NO}$ $\Delta\text{H} = 361.2 \text{ kJ}$

H₂O: x3 $\cancel{6\text{H}_2} + 3\text{O}_2 \rightarrow 6\text{H}_2\text{O}$ $\Delta\text{H} = -1451.1 \text{ kJ}$

Cancel terms and take sum.



Is the reaction endothermic or exothermic?

Determine the heat of reaction for the reaction:



Use the following reactions:

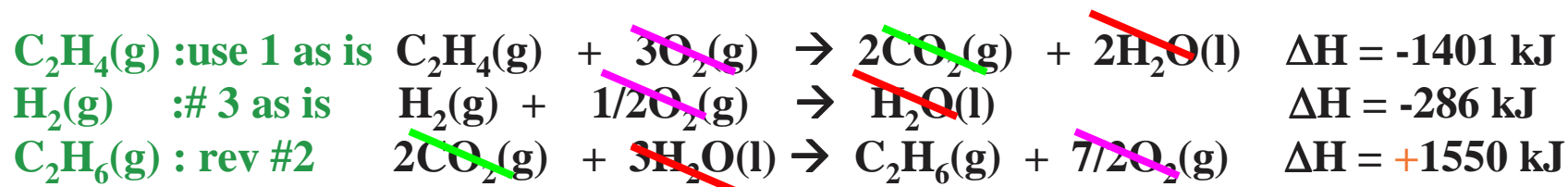


Consult your neighbor if necessary.

Determine the heat of reaction for the reaction:



Use the following reactions:



Summary:
enthalpy is a state function
and is path independent.



2nd method : Standard Molar Enthalpy of Formation

- Symbol (ΔH°_f)
- Change in enthalpy when 1 mol of a compound is formed directly from its elements in their most stable state at standard ambient temperature and pressure (SATP: 25°C and 100kPa) and all solutions have a 1.0mol/L concentration.

Writing Formation Equations

- always write equation where 1 mole of compound is formed (even if you must use non-integer coefficients)

$\text{NO}_2(\text{g})$:



$$\Delta H_f^\circ = 34 \text{ kJ/mol}$$

$\text{CH}_3\text{OH}(\text{l})$:



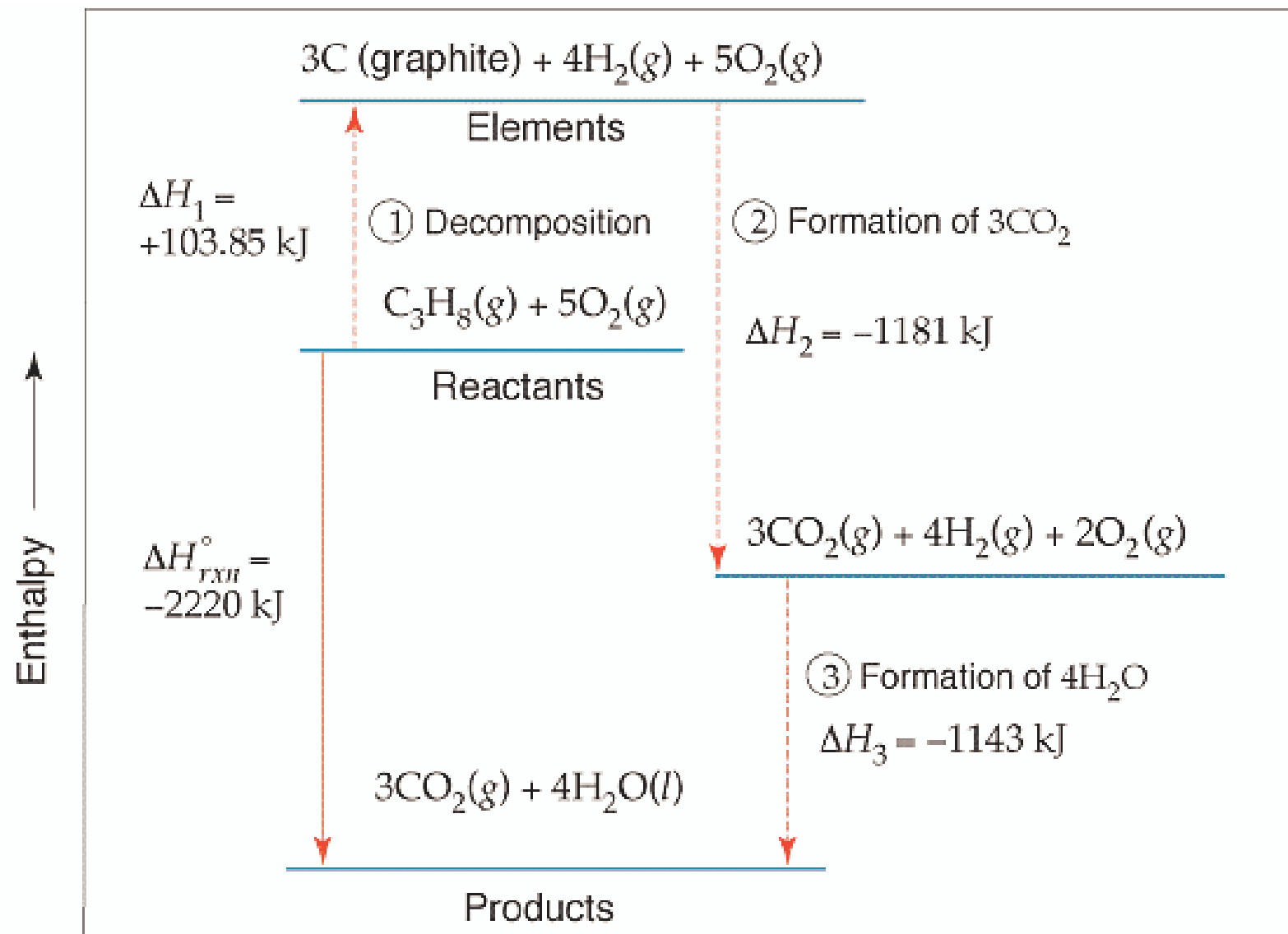
$$\Delta H_f^\circ = -239 \text{ kJ/mol}$$

Using Standard Enthalpies of

$$\Delta H_{\text{reaction}}^{\circ} = \sum n_p \overset{\text{Formation}}{\Delta H_{\text{f(products)}}^{\circ}} - \sum n_r \Delta H_{\text{f(reactants)}}^{\circ}$$

where

- n = number of moles of products/reactants
 - \sum means “sum of”
 - $\Delta H_{\text{f}}^{\circ}$ is the standard enthalpy of formation for reactants or products
-
- $\Delta H_{\text{f}}^{\circ}$ for any element in standard state is zero so elements are not included in the summation



Thermodynamic Quantities of Selected Substances @ 298.15 K

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Aluminum				CF ₄ (g)	-679.9	-635.1	262.3
Al(s)	0	0	28.32	CH ₄ (g)	-74.8	-50.8	186.3
AlCl ₃ (s)	-705.6	-630.0	109.3	C ₂ H ₂ (g)	226.7	209.2	200.8
Al ₂ O ₃ (s)	-1669.8	-1576.5	51.00	C ₂ H ₄ (g)	52.30	68.11	219.4
				C ₂ H ₆ (g)	-84.68	-32.89	229.5
Barium				C ₃ H ₈ (g)	-103.85	-23.47	269.9
Ba(s)	0	0	63.2	C ₄ H ₁₀ (g)	-124.73	-15.71	310.0
BaCO ₃ (s)	-1216.3	-1137.6	112.1	C ₄ H ₁₀ (l)	-147.6	-15.0	231.0
BaO(s)	-553.5	-525.1	70.42	C ₆ H ₆ (g)	82.9	129.7	269.2
Beryllium				C ₆ H ₆ (l)	49.0	124.5	172.8
Be(s)	0	0	9.44	CH ₃ OH(g)	-201.2	-161.9	237.6
BeO(s)	-608.4	-579.1	13.77	CH ₃ OH(l)	-238.6	-166.23	126.8
Be(OH) ₂ (s)	-905.8	-817.9	50.21	C ₂ H ₅ OH(g)	-235.1	-168.5	282.7
Bromine				C ₂ H ₅ OH(l)	-277.7	-174.76	160.7
Br(g)	111.8	82.38	174.9	C ₆ H ₁₂ O ₆ (s)	-1273.02	-910.4	212.1
Br(aq)	-120.9	-102.8	80.71	CO(g)	-110.5	-137.2	197.9
Br ₂ (g)	30.71	3.14	245.3	CO ₂ (g)	-393.5	-394.4	213.6
Br ₂ (l)	0	0	152.3	HC ₂ H ₃ O ₂ (l)	-487.0	-392.4	159.8
HBr(g)	-36.23	-53.22	198.49				
Calcium				Cesium			
Ca(g)	179.3	145.5	154.8	Cs(g)	76.50	49.53	175.6
Ca(s)	0	0	41.4	Cs(s)	0	0	85.15
CaCO ₃				CsCl(s)	-442.8	-414.4	101.2
(s, calcite)	-1207.1	-1128.76	92.88	Chlorine			
CaCl ₂ (s)	-795.8	-748.1	104.6	Cl(g)	121.7	105.7	165.2
CaF ₂ (s)	-1219.6	-1167.3	68.87	Cl ⁻ (aq)	-167.2	-131.2	56.5
CaO(s)	-635.5	-604.17	39.75	Cl ₂ (g)	0	0	222.96
Ca(OH) ₂ (s)	-986.2	-898.5	83.4	HCl(aq)	-167.2	-131.2	56.5
CaSO ₄ (s)	-1434.0	-1321.8	106.7	HCl(g)	-92.30	-95.27	186.69
Carbon				Chromium			
C(g)	718.4	672.9	158.0	Cr(g)	397.5	352.6	174.2
C(s, diamond)	1.88	2.84	2.43	Cr(s)	0	0	23.6
C(s, graphite)	0	0	5.69	Cr ₂ O ₃ (s)	-1139.7	-1058.1	81.2
CCl ₄ (g)	-106.7	-64.0	309.4				
CCl ₄ (l)	-139.3	-68.6	214.4				

Example 1

- Calculate the standard enthalpy change for the reaction that occurs when ammonia is burned in air to make nitrogen dioxide and water



Example 2

- Calculate the standard enthalpy change for the following reaction:



Example 3

- Compare the standard enthalpy of combustion per gram of methanol with per gram of gasoline (it is C_8H_{18}).

Homework

- Read pages 312-324
- Must Do:
 - Page 316 #41,43
 - Page 323 #53,55,58
- Extra Practice:
 - Page 324 #4,5,8,9